FACS Availability Summary

- **FACS Starting Availability In LRPT Bands Is 100% Of Design**
  - At 40° N Latitude FACS' System Design Goal For Availability is
    - For 5° Elevation Mask Angle
  - Exclusive Use Until METOP-1 Launched in
    - Availability Unchanged By Using Band Hopping
- **Transitional Sharing Of LRPT and APT Channels With 2 METSATs in Each Maintains 100% of Design Goal For**
  - Most Likely Situation With AM & PM METSATs
  - See Analysis On Following Charts
- **Worst Case Transitional Sharing Of LRPT and APT Channels With 5 METSATs Each Band Achieves 97% of Design Goal**
  - Highly Unlikely Situation
  - See Analysis On Following Charts
- **Exclusive Use Of ATP Channels After 2006 Results In 100% Availability**

Figure 1. **FACS Availability With NOAA Spectrum Sharing in the 137 - 138 MHz Band ("System B" proposed by Leo One USA).**

The initial FACS availability using the NOAA LRPT bands is 100 percent of the FACS design goal since there are no METSATs operating in these bands until 2002. FACS would experience exclusive use of the LRPT bands until 2002 when the European METSAT METOP-1 is projected to be launched. The FACS availability is unchanged by this event if band hopping is implemented at this time. That is, the FACS satellites that overlap coverage with the METSAT would need to use the opposite LRPT band segment during times of overlapping coverage.

The transitional sharing of the LRPT band and APT (or TIP) channels with two (2) METSATs in each band maintains 100% of the FACS availability design goal. Thus, even after the second LRPT band NOAA METSAT is launched in December 2003, 100% of the FACS design goal is potentially maintained. Two satellites in each band assumes that only an AM and PM METSAT constellation is maintained in both the LRPT and APT bands/channels. In the worst case of five active METSATs in both the LRPT and APT bands/channels, FACS can still achieve 97% of its design goal.

FACS can again achieve 100% of its design goal after 2006 when the APT channels become exclusively available. Continued sharing of the LRPT band will be required in order to accommodate the required number of FACS downlink frequency channels.

Figure 2 summarizes the transitional sharing availability parameters used in this evaluation below. The constellation parameters used were those described in the most recent FACS amendment.[3] The METSATs chosen correspond to the current NOAA and DMSP satellites and are used as representative of future METSAT constellations.

FACS Transitional Availability Evaluation

- **26 Satellite Constellation**
  - 24 Satellites Inclined 66 Degrees, 1000 Km
  - 2 Satellites Inclined 83 Degrees, 1000 Km Altitude
- **Up to 5 NOAA Satellites in APT & TIP**
  - NOAA-14, -12, -11, -10 & -9 Used As
- **Up to 5 NOAA METSATs in LRPT**
  - DMSP Constellation Used As Typical Of Future METSATs
  - DMSP-8, -7, -6, -5 & -3 Used
- **Assumes Band Hopping Employed To Avoid**
- **Results Show Availability Remains High During Worst CaseTransitional**
  - Final Analysis Achieves 97% Of Design Goal For Availability
  - With 2 METSATs in Each Band, Availability Is Essentially Unchanged From Final Analysis Baseline

Figure 2. FACS Transitional Sharing Availability Evaluation Parameters.

[3] Final Analysis Amendment dated February 23, 1996.

FACS Transitional Availability
137-138 MHz MetSat Sharing - Concurrent Sharing Of LRPT & APT Bands With 2 METSATs in Each Band

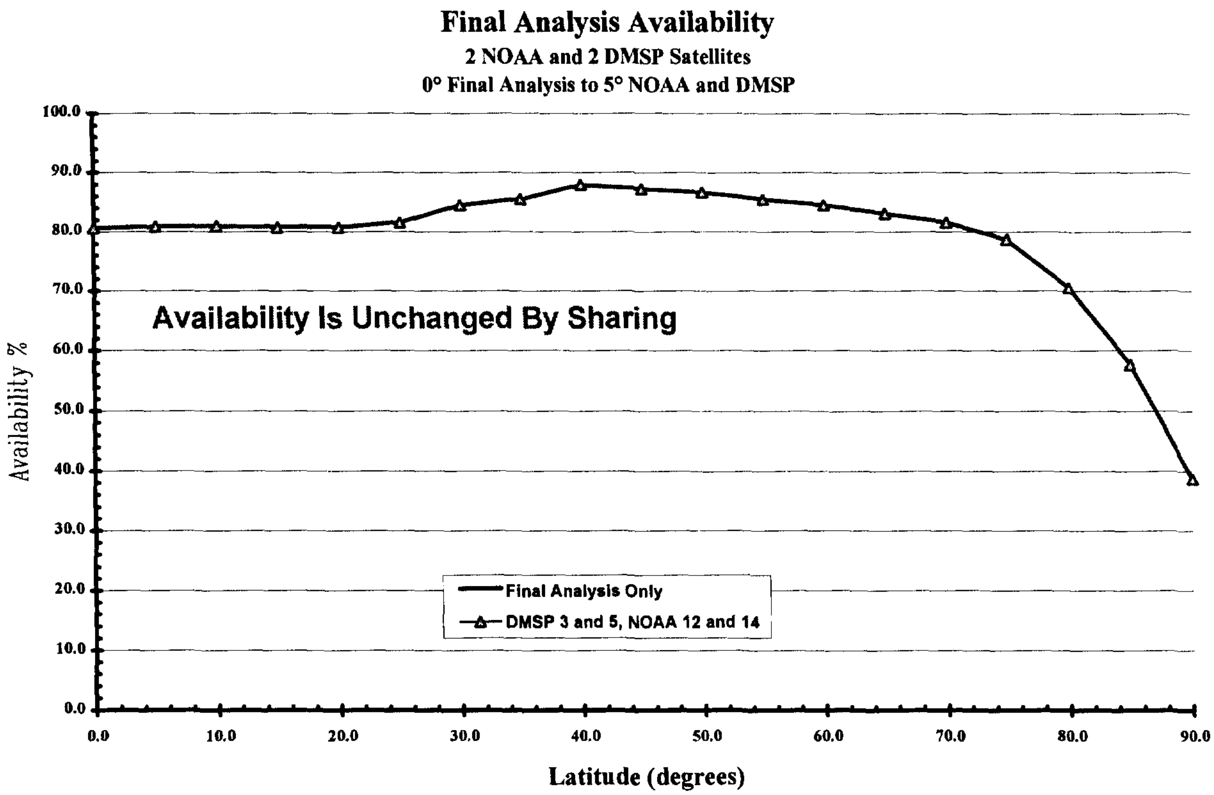


Figure 3. FACS Transitional Availability When Sharing With Two METSATs in Each Band.

Figure 3 shows the FACS availability as a function of user latitude with concurrent sharing of the LRPT and APT bands with two AM and PM METSATs operating in each band. Also shown for reference is the FACS availability with a 5° mask angle as proposed in the FACS application. Leo One USA does not believe operation down to a mask angle of 5° represents a service link with high reliability. However, even at this low mask angle there is essentially *no* *impact to the FACS availability design goal.* As indicated, the FACS availability is approximately 88% at 40° latitude with its five degree elevation mask angle[4].

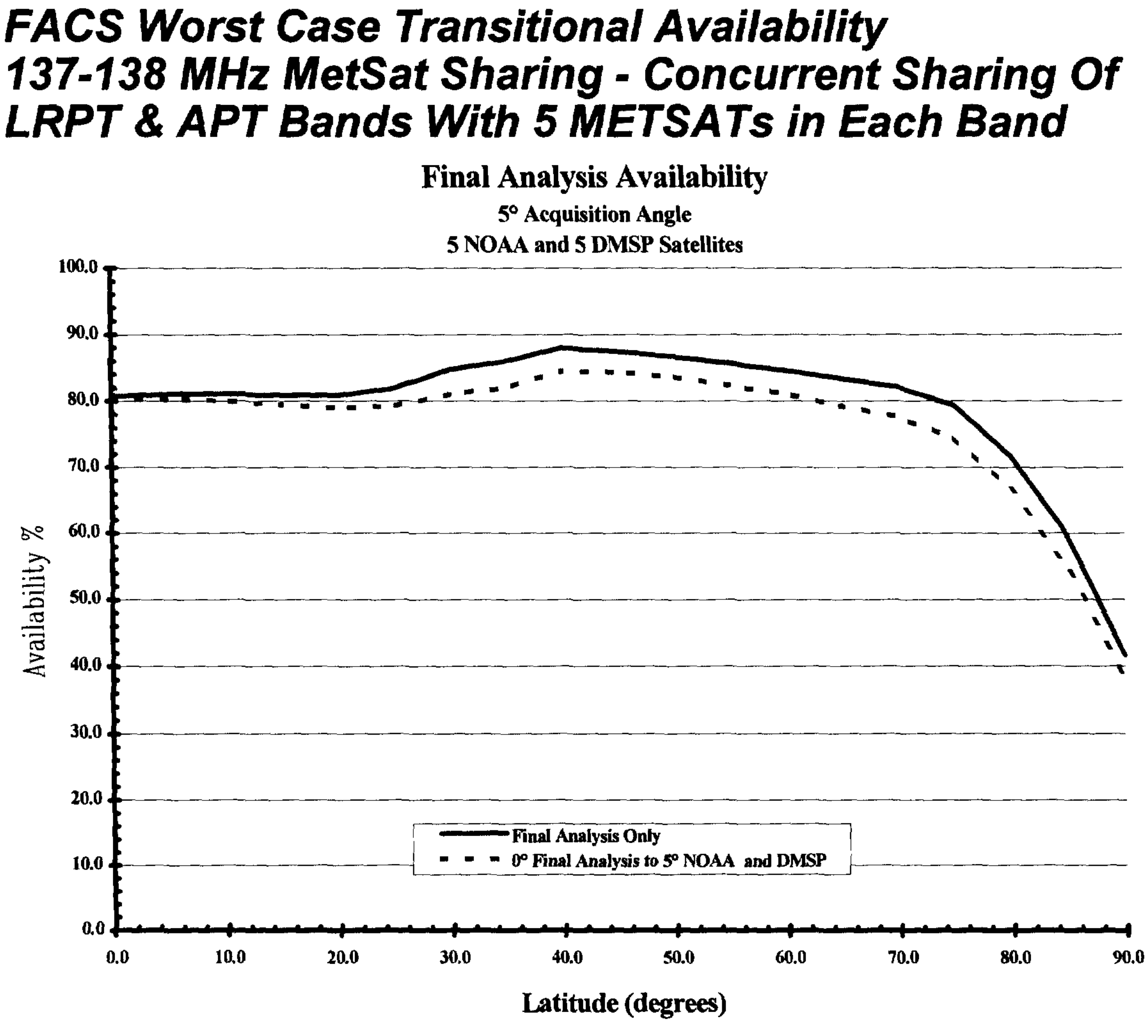


Figure 4. Worse Case FACS Transitional Availability When Sharing With Five METSATs in Each Band.

4 This availability percentage is based on an aggressive expectation of reliable communications down to mask angles of 5 degrees. Leo One USA has used the FACS 5 degree mask angle to ensure the most conservative analysis of the impact of timesharing on the service objectives of FACS. The FACS availability achieved without the burden of timesharing and using a more realistic expectation of 10 degree mask angle is represented in the Autometric Study "Little LEO Constellation Availability Analysis". *See* Appendix B.

Figure 4 shows the worst case FACS transitional band sharing availability when five METSATs are operating in both the LRPT and APT bands. As indicated, the impact to the FACS availability is small. The FACS availability is reduced from 88 percent to approximately 85 percent, which is 97% of the FACS design goal.

This transitional period is projected to only last a few years as NOAA transitions to the LRPT band. The first NOAA METSAT is scheduled for launch in December 2003. This would be the second NPOESS satellite and, together with the METOP-1, constitute an AM and PM constellation. The second METOP-2 satellite is planned for 2006. The second NOAA satellite is scheduled to be launched three and one-half years later in July 2007. At that time the youngest NOAA satellite in the APT bands would be 7 years old and beyond its expected lifetime. Thus, no more than three METSATs are likely to be using the band prior to the APT bands becoming available on an exclusive basis. Since it is unlikely that there will be five METSATs operating in both the LRPT and APT bands, the FACS availability in all likelihood will exceed the worst case 97% estimate. Following this transitional period, the APT band will be available on an exclusive basis resulting in 100% of the FACS availability design goal being achievable.

Leo One USA agrees with FACS that Autometrics has substantial capabilities in evaluating satellite orbit dynamics. Consequently, for the purpose of independent validation, Leo One USA itself commissioned Autometrics to engage in additional analysis of the Commission's band sharing proposal which would incorporate frequency hopping into their earlier analysis. This Study appears as Appendix D and supports the conclusions drawn here that with the incorporation of frequency hopping techniques, availability of the FACS system increases to nearly one hundred percent.

The Leo One USA analysis, further validated by the Autometrics analysis expanded to incorporate frequency hopping, justifies the Commission's approach to band sharing.

APPENDIX D

APPENDIX D

AUTOMETRIC TIME SHARING ANALYSIS

Meteorological Satellite (MetSat) Systems Interference Analysis

Autometric, Inc. was tasked by LEO One USA to analyze the mask angle protection requirements for the NOAA and DMSP MetSat Systems in response to the technical questions from FCC Notice of Proposed Rule Making (FCC 96-426). Specifically, analyses were to be conducted between NOAA MetSats and Non-Voice, Non-GEO (NVNG) Satellites in the 137 - 138 MHz band, and between DMSP MetSats and NVNG Satellites to simulate the future NOAA MetSats noted in FCC 96-426. DMSP satellites are used to represent possible future satellites in the NOAA LRPT band. MetSat bands are each divided into 2 channels to prevent internal interference. This study assumes NVNG satellites have the ability to switch to the opposite NOAA MetSat-band/channel whenever NVNG satellite footprints overlap that of a MetSat footprint.

Analysis Approach

Autometric's automated visualization tool, Omni, was used to conduct the analysis using LEO satellite system parameters contained in current FCC license proposals. This tool provides the means to visualize the results of complex simulations involving spatial relationships between user defined objects such as satellites. It allowed non-interference availability to be calculated for those times when there was no coverage footprint overlap of NOAA and DMSP satellites with a selected NVNG satellite (results illustrated in Figures 1 & 2 and problem definition illustrated in Figure 3). The FACS Constellation was chosen for a representative analysis of this non-interference availability using the parameters summarized in Table 1, taken from the most recent FCC license proposal filing FACS (15 Nov 94 and latest amendment dated 23 Feb 96).

Results

The **FACS constellation is impacted by an average of 2.19% due to the interaction of the FACS 0-degree mask angle footprint with that of the MetSat 5-degree mask angle footprints** as depicted graphically in Figures 1 and 2. *Note: Interference is calculated with 0 deg mask angle while Downlink Availability is calculated with higher mask angles.*

Figure 1. System Downlink Availability @ 10 deg Mask Angle with and without MetSat Interference

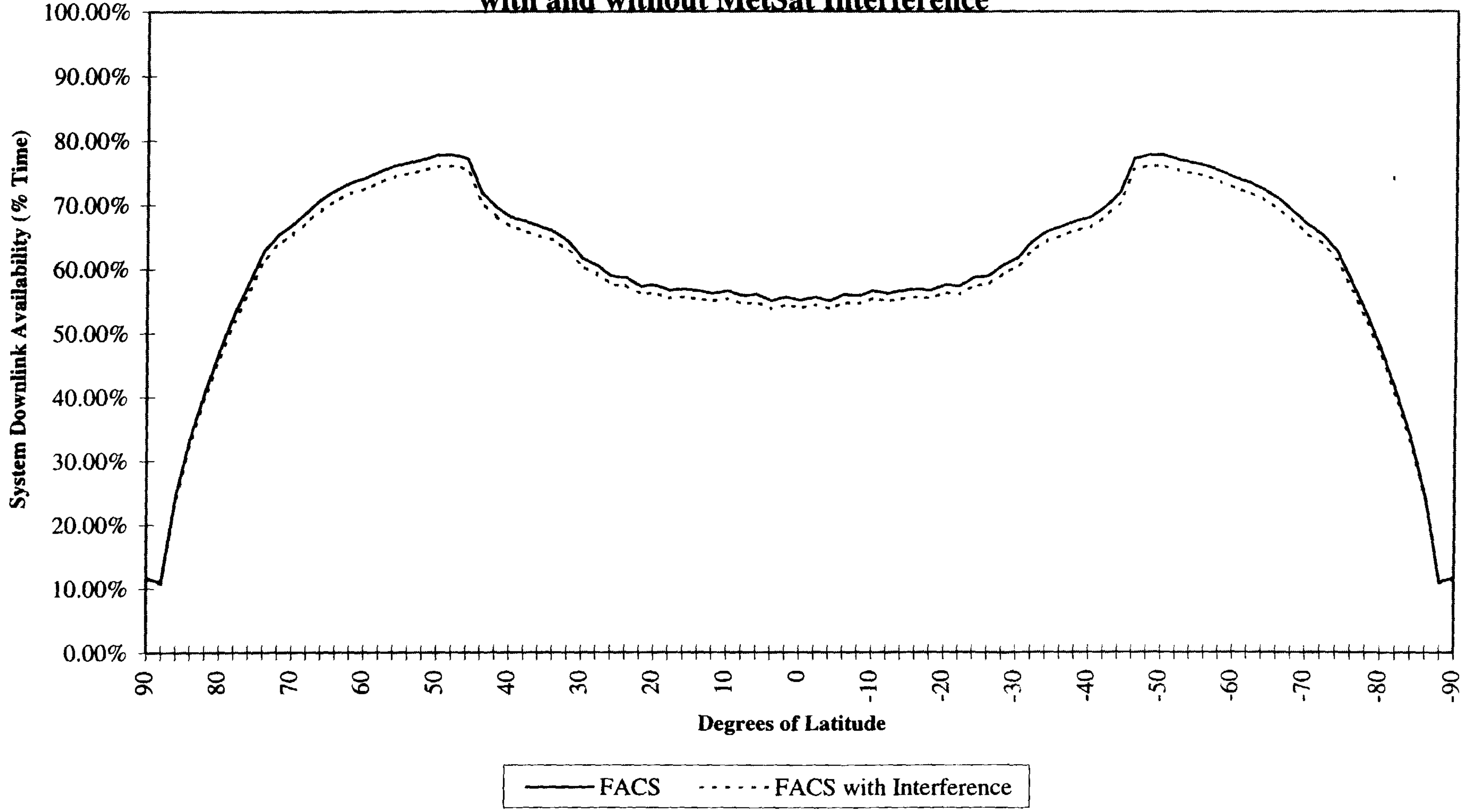
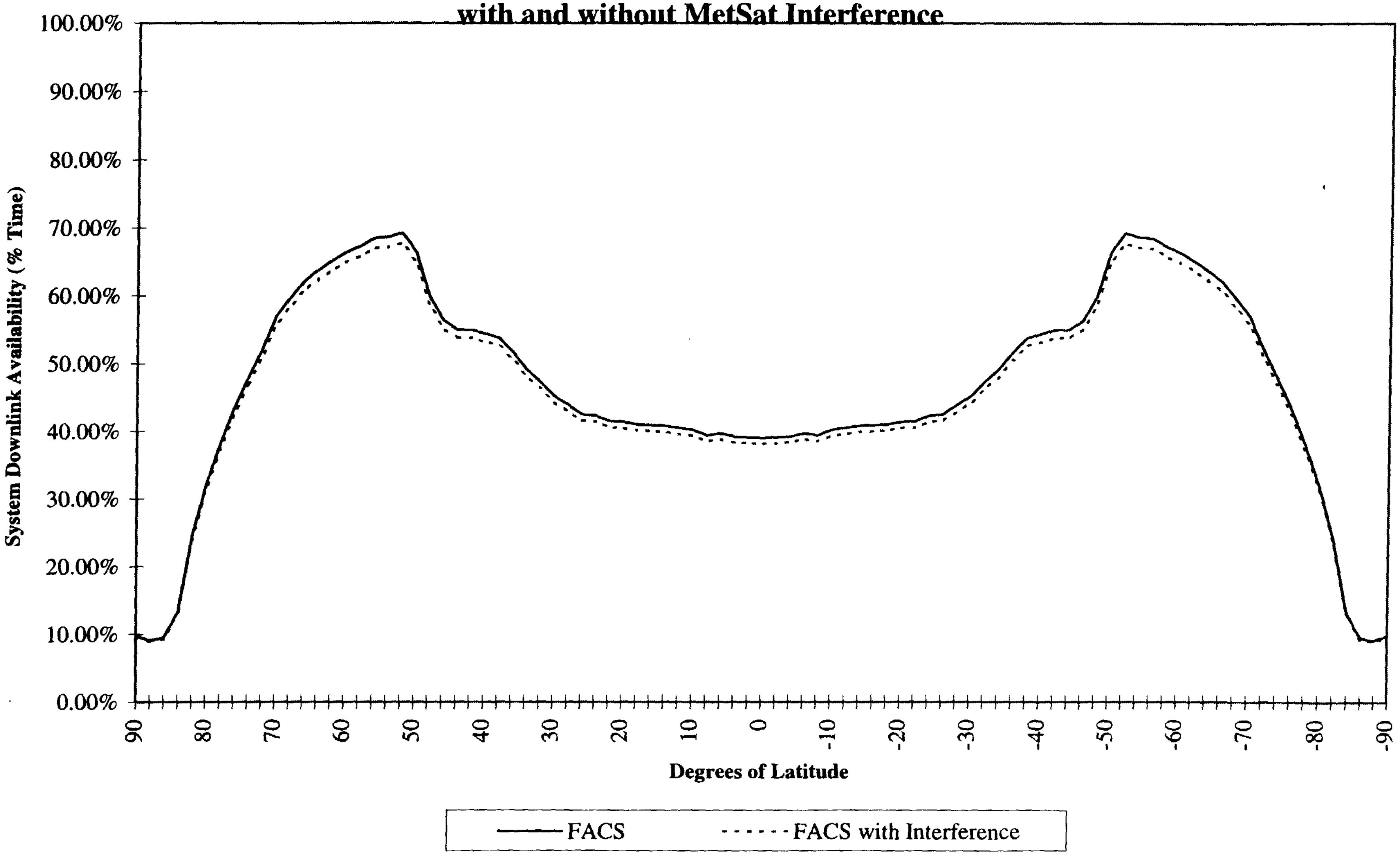


Figure 2. System Downlink Availability @ 15 deg Mask Angle with and without MetSat Interference



Assumptions and Definitions Underlying the Analyses

1. A FACS downlink interference analysis was conducted using a FACS mask angle of 0-degrees and MetSat mask angles of 5-degrees (mask angle is sometimes referred to as ground elevation angle).

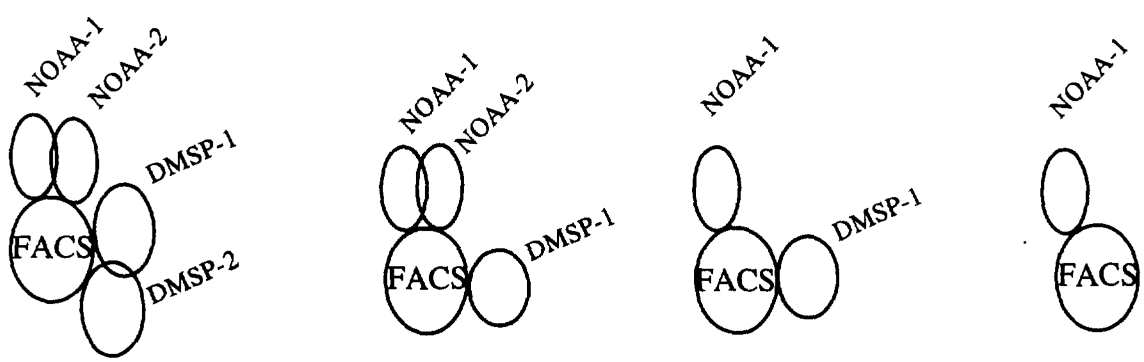
2. Theoretical downlink availability is defined as the percentage of total time one or more satellites are in view of a ground location to allow the sending or receiving of information (without regard to overlapping MetSat footprints).

3. Downlink interference with MetSats is defined as the average percentage of total time one satellite is overlapping with 2 NOAA and 2 DMSP MetSat footprints simultaneously. This average percentage was weighted by the theoretical downlink availability to produce Figures 1 and 2.

4. The satellites' element set epoch times used for this study are shown in Table 2. The Epoch time used for the FACS constellation was Day 366/1996 (Dec 31, 1996) at 00:00:00. Simulations began on Day 1/1997 (Jan 1, 1997) at 00:00:00 and were run for 24 hours. This period of time was used due to study time constraints.

5. Downlink availability reported in this study is derived strictly from geometric considerations and does not account for possible RF attenuation.

6. Downlink availability was assessed as indicated graphically in Figure 3:



No Downlink Availability | One Channel Available Without Interference. | Two Channels Available Without Interference. | Three Channels Available Without Interference.

Figure 3. FACS Downlink Availability When Interference Exists With MetSat Footprints.

	FACS
Total # of SATs	26
Total # of Planes	6
Primary Plane	
# of Planes	4
SATs per Plane	6
Inclination (deg)	66
RAAN (deg)	0, 45, 90, 135
Intra-Plane Sat Spacing (deg)	60
Inter-Plane Sat Spacing (deg)	0
Secondary Planes	
# of Planes	2
SATs per Plane	1
Inclination (deg)	83
RAAN (deg)	0,90
Intra-Plane Sat Spacing (deg)	-
Inter-Plane Sat Spacing (deg)	0
Eccentricity	0
Altitude (km)	1000
Subscriber Downlink Rate (kbps)	19.2

Table 1
FACS Orbital Parameters and Constellation Design

DMSP	3	5	6	7	8
Epoch	96-06-20 11:42:16.568	96-06-20 19:12:10.004	96-06-20 118:48:16.135	96-06-20 113:50:48.714	96-06-20 114:57:38.644
Semi Major Axis (km)	7218.9324	7160.99047	7223.94183	7228.23178	7228.13706
Inclination (deg)	98.7696	98.5975	98.9472	98.8257	98.8375
Eccentricity	0.0013175	0.0078857	0.0011837	0.0012308	0.000847
RAAN (deg)	2.7327	243.9019	190.0973	231.4109	175.0407
Arg of Perigee (deg)	246.0685	159.0482	216.0916	166.1448	49.5175
Mean Anomaly (deg)	113.9113	201.3958	143.946	194.0061	310.6733

Table 2
DSMP Orbital Parameters

NOAA	10	11	12	14	9
Epoch	96311.87778918	96311.33949132	96311.62988793	96311.82526843	96311.81183
Inclination (deg)	98.5309	99.1762	98.5502	98.9595	98.9323
RAAN (deg)	304.9110	333.1048	326.6122	256.9694	16.7080
Eccentricity	0.0012521	0.0011164	0.0011827	0.0008677	0.0013988
Arg of Perigee (deg)	302.2737	198.8969	219.0256	195.2183	271.9212
Mean Anomaly (deg)	57.7228	161.1775	141.0068	164.8736	88.0355
Mean Motion	14.2500824	14.1310883	14.2266659	14.1162322	14.1381450

Table 3
NOAA Orbital Parameters

APPENDIX E

APPENDIX E

ANALYSIS OF SHARING WITH GE STARSYS

APPENDIX E

ANALYSIS OF SHARING WITH GE STARSYS

GE Starsys can accommodate a 2nd round narrowband Little LEO system operating downlinks in the 137 - 138 MHz band.

GE Starsys states in its 25 April 1994 amendment that "[t]he sharing agreement allows all three applicants to operate successfully while leaving room for additional applicants at a later date." Since that time two potentially significant events have occurred: 1) the April 1993 draft revision of ITU-R SA.1027 was further revised in June 1995 and 2) Orbcomm modified its requested channel assignments on three occasions: 12 August 1994, 15 November 1994, and 20 October 1995.

GE Starsys' 25 April 1994 amendment includes an analysis showing that its proposed power flux density in the 137 - 138 MHz band is in compliance with the April 1993 draft revision of ITU-R SA.1027. The June 1995 revision would require that GE Starsys reduce its PFD by at most 0.9 dB. This is not a significant change.

The interference from Orbcomm's downlinks into GE Starsys' is proportional to the GE Starsys CDA downlink matched filter response integrated over the spectrum used by Orbcomm. Using this measure, the interference decreased by 0.9 dB from Orbcomm's 21 November 1993 amendment, the public record on 25 April 1994 when GE Starsys filed its amendment, and Orbcomm's 20 October 1995 modification. Thus, Orbcomm's change in channel assignments effectively cancels out the effect of the June 1995 SA.1027 PFD reduction.

In conclusion, there have been no material changes since GE Starsys filed its 25 April 1994 amendment. Hence, GE Starsys can accommodate a 2nd round narrowband Little LEO system operating downlinks in the 137 - 138 MHz band. Supporting material is provided in Attachment 1.

Attachment 1

GE Starsys plans to use a bent-pipe transponder for its inbound links with subscriber terminals uplinking 905 kHz bandwidth spread-spread spectrum signals in the 148 - 149.9 MHz band and the satellites downlinking these signals in the 137 - 138 MHz band to the GE Starsys gateways (CDAs).

A chronology of relevant FCC and GE Starsys documents is attached. A summary of GE Starsys CDA downlink power flux density (PFD) and sharing quotes is provided in Table 1.

Table 1. Summary of GE Starsys 137 - 138 MHz Gateway Downlink PFD and Sharing Quotes

Date	Document	GE Starsys PFD dB(W/m^2/4 kHz)	137 - 138 MHz Band Sharing Quotes
4 May 90	GE Starsys Application	-153.5	-
6 Dec 91	Modified AP4	-147.6	-
16 Sep 92	NRMC Report	-	May allow for entrants in addition to the three applicants.
14 Jan 93	Allocation R & O	-	Additional licensees may be accommodated in the future.
14 Jan 93	NPRM	-	The system proponents ... agree that sharing ... with future systems is possible.
9 Jun 93	LEOTELCOM-2 AP3	-150.6	-
21 Oct 93	NVNG Rules R & O	-	Both Orbcomm and GE Starsys continue to assert their abilities to share their proposed service link frequencies with future systems.
25 Apr 94	GE Starsys Amendment	-156.2	The sharing agreement allows all three applicants to operate successfully while leaving room for additional applicants at a later date.

The Orbcomm system is licensed to operate downlinks in the 137 - 138 MHz band. Figure 1 shows the various channel assignments that Orbcomm has requested from its original 21 September 1990 application through its 20 October 1995 modification. The public record at the time of GE Starsys' 25 April 1994 amendment reflected Orbcomm's 21 December 1993 amendment.

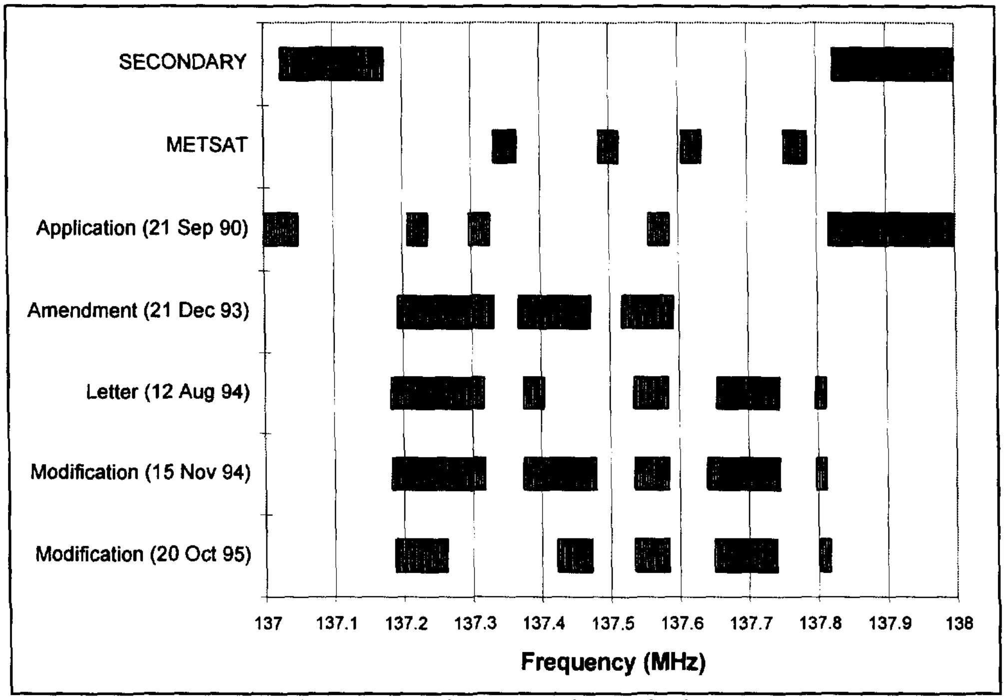


Figure 1. Orbcomm Channel Plans

GE Starsys' CDA downlink matched filter response can be modeled as:

$$MF(\Delta f) = \left[\frac{\cos\left(\frac{3 \cdot \pi \cdot \Delta f}{B_{SS}}\right)}{1 - 36 \frac{(\Delta f)^2}{B_{SS}^2}} \right]^2$$

where Δf is the offset from the center frequency and B_{SS} is the spreading bandwidth. The interference from Orbcomm's downlinks into GE Starsys' is proportional to this response integrated over the spectrum used by Orbcomm.

Table 2 shows the relative interference levels for each of the Orbcomm channel plans.

Table 2. Relative Interference from Orbcomm into GE Starsys

	Integrated Response	Interference Relative to 21 Dec 93 Amendment
Application (21 Sep 90)	0.23	-4.9 dB
Amendment (21 Dec 93)	0.72	0.0 dB
Letter (12 Aug 94)	0.53	-1.3 dB
Modification (15 Nov 94)	0.84	0.7 dB
Modification (20 Nov 95)	0.59	-0.9 dB

The 1994 editions of Recommendations ITU-R SA.1026[1] and SA.1027[2] do not address the 137 - 138 MHz band. These recommendations are currently being revised. The 7 June 1995 draft revisions[3] include the 137 - 138 MHz band. The revised draft SA.1026 recommends interference levels to be used as permissible total levels of interfering signal power. The revised draft SA.1027 recommends single entry interference levels to be used as sharing criteria (including power flux density limits).

GE Starsys' 25 April 1994 amendment anticipated the revision of SA.1027, and provided an interference analysis based on an April 1993 draft. The final June 1995 draft reflects values 0 to 5 dB less than those used by GE Starsys in its analysis as shown in Table 3.

Table 3. Delta Between Draft SA.1027 PFD Limits and Values Used by GE Starsys in 25 April 94 Amendment

Type of Earth Station	PFD to be exceeded no more than 20% of the time	PFD to be exceeded no more than p% of the time
analog receiver 2 dBic antenna gain	5 dB	2 dB
digital receiver 10 dBic antenna gain	1 dB	0 dB
digital receiver 2 dBic antenna gain	5 dB	1 dB

1 Interference Criteria for Space-to-Earth Data Transmission Systems Operating in the Earth Exploration-Satellite and Meteorological-Satellite Services using Satellites in Low-Earth Orbit.

2 Sharing and Coordination Criteria for Space-to-Earth Data Transmission Systems Operating in the Earth Exploration-Satellite and Meteorological-Satellite Services using Satellites in Low-Earth Orbit.

3 Documents 7/1009-E and 7/1010-E, respectively.

GE Starsys' analysis concludes[4] that the interference criteria for an analog receiver with 2 dBic antenna gain is never exceeded with a minimum margin of 6.3 dB. Thus, even with the 5 dB reduction, GE Starsys can be assumed to comply with the new limit. For the digital receiver 2 dBic antenna gain, GE Starsys concludes that the interference criteria is never exceeded with a minimum margin of 4.1 dB. Thus with the 5 dB reduction, GE Starsys is still within less than 1 dB of the limit. GE Starsys concludes that the interference criteria is exceeded for the 10 dBic antenna gain earth station. They then point out that their computations were worst case and that that scenario will rarely occur and coordination could be done by reducing satellite transmitter power during these events. The 1 dB PFD reduction does not effect this argument.

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[4] Section 5.4.1.4 of 25 April 1994 Amendment.

Chronology of Relevant GE Starsys and FCC Documents

4 May 1990

GE Starsys files initial FCC application stating:

- "Outbound downlink channels analysis (satellite -> user terminals): … Downlink margin: +3 dB … Power flux density at the ground in any 4 kHz band: -141.5 dBW/m^2/4 kHz."[5]
- "Inbound downlink channels analysis (satellite -> ground station): … Downlink margin: +5.5 dB … Power flux density at the ground in any 4 kHz band: -153.5 dBW/m^2/4 kHz."[6]
- "This band [137 - 138 MHz] is allocated on a Primary Basis to Space-to-Earth operations (TIROS, LANDSAT, IMP … satellites)."[7]
- "The low Power Flux Density (-141.5 dBW/m^2/4 kHz) of the outbound downlink referenced to a 4 kHz bandwidth combined with spread spectrum should permit sharing the (137 - 138 MHz) VHF bandwidth without coordination with other Space to Earth services."[8]

No meaningful interference analysis is provided.

25 May 1990

GE Starsys files amendment to FCC application addressing ownership. No technical changes.

31 October 1991

LEOTELCOM AP4 received by the BR, published as AR11/A/795, states an altitude of 1200 km and provides the following parameters for emissions in the 137 - 138 MHz band:

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[5] Page VII-9.

[6] Page VII-12.

[7] Page VII-25, 7.1.

[8] Page VII-25, 7.1.1.

- Will be operated in accordance with the provisions of RR 342 until a competent Radio Conference adopts appropriate allocations and sharing conditions

- Maximum satellite transit spectral power density of -27 dBW/Hz and maximum EIRP of +13 dBW.

- Maximum transmit antenna gain of +4 dBi.

- Earth Station receive antenna noise temperature of 1200 °K

These parameters result in a peak power flux density at the Earth's surface of -119.6 dB(W/m^2/4 kHz).

6 December 1991

FCC submits modified AP4 to the IFRB. Page 3 of the modified AP4 form shows a 1 MHz bandwidth satellite downlink transmission in the 137 - 138 MHz band with a maximum power density of -55.0 dBW/Hz, presumably this is GE Starsys's spread-spectrum downlink signal. The resulting peak power flux density at the Earth's surface is -147.6 dB(W/m^2/4 kHz).

16 September 1992

Report of the Below 1 GHz LEO Negotiated Rulemaking Committee (at page 8) issued referencing Orbcomm/Starsys/VITA sharing plan, LEOAC-15, which states:

- "... can share the same limited amount of spectrum and may allow for entrants in addition to the three applicants who submitted LEOAC-15, using either approach."

- "CDMA is also accommodated in the downlink direction with 855 kHz in the 137 - 138 MHz band for CDMA, but the services will have to operate, in part, in portions of the band which are designated as secondary for the NVNG satellite service. The downlink spectrum will also accommodate additional CDMA entrants within the limits of existing noise levels and will be subject to sharing the spectrum on a secondary basis with the METSATs that already use several frequency bands in the spectrum."

- "... there may be unused spaces for one or more 50 kHz FDMA feeder links in the 137 - 138 MHz downlink band."

- "In the downlink direction, DCAS FDMA uses channels in the portion of the 137 - 138 MHz band where NVNG is currently co-primary. Additional DCAS FDMA systems should be able to share these channels or user other unused channels in the co-primary portion of the same band for transmitting downlink data."

- "The downlink band activity must share the spectrum with CDMA by using reverse polarity, geographical separation of the satellites, and location of feederlinks away from the center of the CDMA signals."

14 January 1993

NVNG MSS Allocation Report and Order, FCC 93-29, adopted, stating:

- "GE Starsys intends to avoid interference by using spread spectrum techniques and operate in the 137 - 138 MHz and 148 - 149 MHz bands on a non-interference basis."[9]

- 137 - 138 MHz. ... "We believe that the three petitioners can be accommodated in the band and that additional licensees may be accommodated in the future."[10]

- "Until January 1, 2000, the use of the 137 - 138 MHz band by the MSS will be secondary to Government satellite operations in the subbands: 137.333 - 137.367, 137.485 - 137.515, 137.605 - 137.635 and 137.753 - 137.787 MHz.[11]

14 January 1993

NVNG MSS Rules and Policies NPRM adopted, stating:

- "The system proponents represented on the Committee agree that sharing of the available spectrum with future systems is possible ..."[12]

- "... since some room appears to exist for future entrants, ..."[13]

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9 Paragraph 12.

10 Paragraph 13.

11 US318.

12 Paragraph 7.

13 Paragraph 7.

9 June 1993

LEOTELCOM-2 request for coordination AP3 received by the BR, published in RES46/C/50, states a 1300 km altitude and operation in the 137.0475 - 137.9525 MHz band with the following parameters:

- Center frequency of 137.5 MHz
- Bandwidth of 905 kHz.
- Emission designator of 894KG1D.
- Total peak power of +7 dBW
- Maximum power density of -49.3 dBW/Hz.
- Maximum Earth Station antenna gain of +17 dBi.
- Receive noise temperature of 1000° K
- Iso-flux space station antenna with nadir gain of -4 dBi and gain at 40° of +4dB.

These parameters result in a peak power flux density at the Earth's surface of -150.6 dB(W/m^2/4 kHz).

21 October 1993

-

NVNG MSS Rules Report and Order, FCC 93-478, adopted, stating:

- "... we may require licensees to coordinate not only with future licensees, but with future applicants as well. ... we have stated our intent to intervene at an early stage if such cooperation is not forthcoming ...."[14]
- "... since frequencies are not exclusively assigned to any licensee, the coordination process may result in a reduction of the operational flexibility of an existing system."[15]

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14 Paragraph 9.

15 Footnote 15.